PB-218 296

MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS BENTON RESERVOIR SALINE RIVER ARKANSAS

Public Health Service
Dallas, Texas

November 1960

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

12

PB 218 296

MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS

BENTON RESERVOIR

SALINE RIVER

ARKANSAS

RECEIVED
LIBRARY
MAY 13 1969
FWPCA, OHIO BASIN REGION
4676 COLUMBIA PKWY., CINTI, O. 45226

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S Department of Commerce
Springfield VA 22151

In Cooperation with the

DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Vicksburg, Mississippi

NOVEMBER 1960

34

TABLE OF CONTENTS

	Page
LIST OF TABLES	iii
LIST OF FIGURES	iv
I. INTRODUCTION	
Authority	1
Purpose and Scope	1
Acknowledgments	1
II. SUMMARY AND CONCLUSIONS	
Summary	2
Conclusions	3
III. DESCRIPTION OF PROJECT	
Location	5
Stream Flow	5
Water Quality	6
Pertinent Data	6
IV. DESCRIPTION OF STUDY AREA	8
Climate	8
Principal Communities and Industries	8
V. ECONOMICS AND POPULATION	10
Extractive Industries	10
Manufacturing	12
Retail Trade and Service Establishments	13
Population	13
Future Growth	14

TABLE OF CONTENTS (Continued)

Page

VI. WATER REQUIREMENTS

Present Water Use 19

Existing Sources 19

Additional Water Needs 21

Plan for Supplying Future Requirements 24

VII. BENEFITS OF STORAGE 26

Alternative Plan 26

Water Supply Benefits 26

Water Quality Maintenance Benefits 27

VIII. BIBLIOGRAPHY 28

LIST OF TABLES

Page

Table 1. Average Water Quality - Saline River, Water Year 1955. 6

2. Pertinent Data, Benton Reservoir, Arkansas 7

3. Value of Mineral Production - 1953-1958, Saline, Hot Spring, and Bradley Counties, Arkansas 10

4. Value of Crops and Livestock Sold, Saline, Grant, Hot Spring, Dallas, Cleveland, and Bradley Counties, Arkansas 11

5. Number of Firms by Size and Type of Manufacturing, Saline, Grant, Hot Spring, Dallas, Cleveland, and Bradley Counties, Arkansas - 1947 and 1954 12

6. Retail Trade Developments, Saline, Grant, Hot Spring, Dallas, Cleveland, and Bradley Counties, Arkansas 13

7. Rural and Municipal Populations and Major Municipalities, Saline, Grant, Hot Spring, Dallas, Cleveland, and Bradley Counties, Arkansas 14

8. Present Municipal and Industrial Water Use, Saline River Basin, Arkansas 19

9. Ground Water Quality - Saline River Basin. 20

LIST OF FIGURES

		Following Page
Figure 1.	Benton Reservoir Vicinity Map	5
2.	Benton Reservoir Population Projections	18

I. INTRODUCTION

Authority

A Memorandum of Agreement between the Secretaries of the Departments of Health, Education, and Welfare and the Army, executed November 4, 1958, sets forth procedures for coordinating activities in planning and design of water use projects. In a letter dated July 13, 1959, the District Engineer, U. S. Army Engineer District, Vicksburg, requested that the Public Health Service, under the terms of the Memorandum of Agreement, undertake water supply studies regarding the Benton Reservoir, Saline River, Arkansas.

Purpose and Scope

This report presents data and information relevant to the determination of water requirements, to the year 2010, for municipal and industrial purposes in the Saline River Basin and how these needs may be met. Also, as requested by the Corps of Engineers, this report includes an estimate of the annual benefits which could be ascribed to storage allocated to water supply.

Consideration is given to locale, natural resources, economy, and growth prospects together with the effects of existing and future pollution. The evaluation of water needs is founded on forecasts for population increase and industrial expansion developed to the year 2010.

Acknowledgments

Acknowledgment is gratefully made for the assistance of the Arkansas Water Pollution Control Commission; Arkansas State Department of Health; Industrial Research and Extension Center, University of Arkansas; Arkansas State Geological and Conservation Commission; Marion Crist and Associates, Engineers; Little Rock Board of Water Works Commissioners; and the Chambers of Commerce of Benton-Bauxite and Warren, Arkansas.

II. SUMMARY AND CONCLUSIONS

Summary

1. The proposed Benton Dam Site is situated approximately two miles downstream from where the Alum and North Forks (mile 202) join to form the Saline River. This location is about two miles northwest of the center of the city of Benton in Saline County, Arkansas.

2. Water from storage in the proposed reservoir would be available for use throughout the Saline River Basin which encompasses all or part of Saline, Hot Springs, Grant, Cleveland, Ashley, Bradley, Dallas, Drew, Lincoln, and Jefferson Counties.

3. The major population and industrial centers in the basin are the Benton-Bauxite area at the headwaters (mile 200) of the Saline River and the Warren area approximately 60 stream miles above its mouth on the Ouachita River. The Benton-Bauxite area (including the Benton State Hospital) presently has an average municipal and industrial water use of approximately 6.0 mgd which is supplied from the Saline River and its tributaries. The current Warren area municipal and industrial water demand averages 0.75 mgd and is met from wells having an estimated safe yield of 2.0 mgd. The remaining municipal and industrial water requirements within the basin are negligible and are met from ground water sources. Wells in the northern portion of the basin are undependable at pumpages in excess of 50 gpm (0.07 mgd).

4. There are now three relatively small impoundments on tributaries to the Saline River: Brushy Creek Reservoir has a reported firm yield of 20 cfs at Benton; Little Rock Water Board's Lake Winona on Alum Fork with a firm yield of 32 cfs is used by the Little Rock Water Works system (ultimately discharged to the Arkansas River); while Hurricane Lake, having an estimated safe yield of 7.5 cfs, furnishes industrial water for the Reynolds Metal Company alumina plant at Bauxite.

5. Major industrial activity centers around alumina production in the Benton-Bauxite area and agriculture, wood and wood products production in the remainder of the basin and adjoining areas.

6. Municipal and industrial wastes from the Benton-Bauxite area receive secondary treatment before being discharged to the Saline River with no appreciable downstream damage during times of critical stream flow being reported. Warren is currently rebuilding its municipal sewage treatment system to provide secondary treatment for its waste prior to release to the Saline River.

7. The water which would be impounded in the Benton Reservoir is of good quality and can be utilized in most industrial processes after the usual treatment provided for impounded surface water.

Conclusions

1. Although the study area has shown a decrease in population from 93,694 in 1940 to 89,849 in 1960, the projected population for the year 2010 is 157,000 with 117,000 residing in municipal areas. Major centers within the Saline Basin will be the Benton area with an estimated 30,000 inhabitants and the Warren area with an expected population of 35,000.

2. Should a water supply of satisfactory quality and quantity be provided, the dominant industry is expected to be pulp and paper production with an estimated water requirement of 295 mgd for industrial water and water quality maintenance in the Saline and Ouachita Rivers.

3. Municipal and industrial water requirements for the Saline River Basin, excluding that required for pulp and paper, are estimated to be approximately 27.0 mgd. The forecast municipal and industrial water demand in the Benton area will be 22 mgd of this total (5 mgd - municipal demand in the Warren area). Wastes produced in the vicinity of Benton (mile 200) can be returned to the stream after secondary treatment and will be assimilated in the large flow to be provided for the pulp and paper industry expected in the Warren area downstream. Under these stream flow conditions, the treated wastes released in Benton and vicinity should not reduce the quality of the Saline River in the downstream Warren area (mile 60).

4. The controlling water demand will occur in the Warren area, since the water use in the headwaters will be only a very small portion of the needs in the lower reaches of the river. Projections to the year 2010 indicate that storage to yield 130 mgd for municipal and industrial water supply purposes is needed in the Benton Reservoir to serve Warren and environs.

5. In addition to the municipal and industrial requirements, storage to yield 170 mgd for stream quality maintenance with the anticipated waste loadings, after treatment, will be required. This flow will be needed to assimilate the color released to the stream in treated wastes from the projected pulp and paper production facilities. Paper mill waste color is not amenable to removal by existing industrial waste treatment processes. Color (in excess of 75 ppm) will seriously detract from the Saline and Ouachita Rivers' usefulness for municipal or industrial water supply. (Total - 300 mgd = 5 mgd (municipal), 125 mgd (industrial), and 170 mgd (stream quality maintenance).

6. Based on the most reasonable alternative, a single-purpose dam at the proposed Corps of Engineers site, the annual benefit to be derived from storage to provide a firm yield of 130 mgd for municipal and industrial purposes for the Saline River Basin is $562,200.

7. Waste assimilation water is required to permit full development of the pulp and paper industry in the Saline River Basin. Based on the same alternative as that assumed for municipal and industrial water storage, the annual benefit to be derived from storage to provide a firm yield of 170 mgd for stream quality maintenance is $735,180.

III. DESCRIPTION OF PROJECT

Location

The Saline River Basin embraces a drainage area of 3,270 square miles in south central Arkansas[1]. This river has its beginning at the confluence of Alum and North Forks (mile 202) approximately four miles northwest of the city of Benton, Arkansas (see Figure 1). The proposed dam site is about two miles downstream from this junction (mile 200) and two miles from the center of the city of Benton.

The reservoir area will be shaped, in general, like a reversed "L" with the main stem extending in a northerly direction up North Fork, while the base of the "L" will extend westerly covering portions of Alum Fork and Middle and South Forks, which are tributaries of Alum Fork. A portion of the reservoir pool will inundate the existing Brushy Creek Reservoir on North Fork, to be described later. The Saline River is officially navigable from the mouth to mile 119 in the vicinity of the mouth of Hurricane Creek. Throughout its entire length, the channel is obstructed by numerous drift jams, shoals, and sandbars[2].

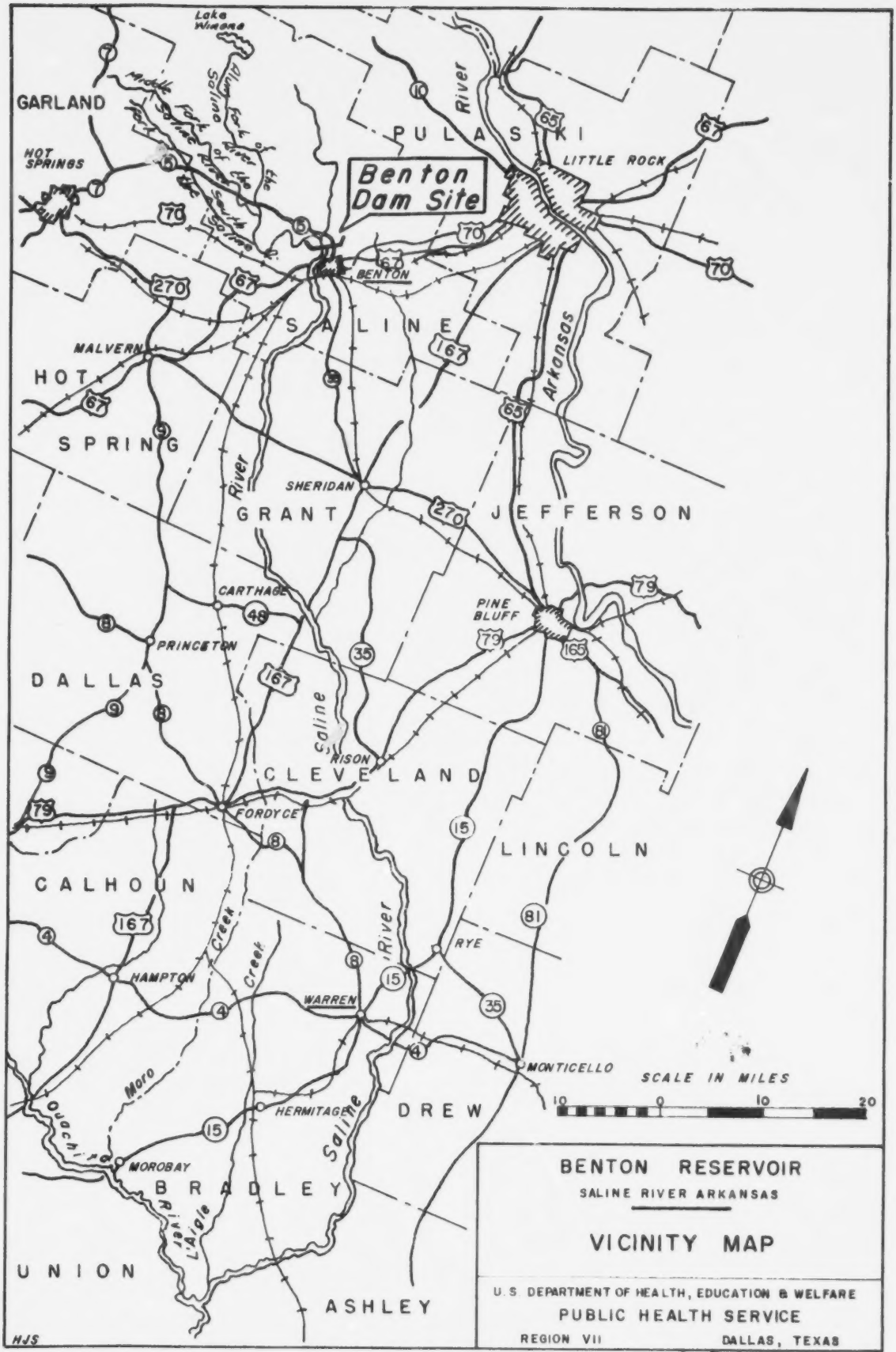
Stream Flow[3]

Stage and discharge information is obtained from two gaging stations, one located southwest of Rye (mile 71) while the other is located one mile west of Benton (mile 199). Both are maintained by the U. S. Geological Survey.

The Rye gaging station, being near the mouth of the stream, most nearly reflects the stream discharge conditions prevailing within the watershed. At this point, there is a total drainage area of 2,062 square miles (of 3,270) with an average discharge (21 years) of 2,757 cfs. Maximum flow of record, 70,500 cfs, occurred on May 3, 1958. Minimum discharge of 3.5 cfs was observed on September 27 and 28, 1954.

The Benton gaging station provides an indication of the discharge conditions prevailing at the proposed dam site. Total drainage area at this gaging station is 569 square miles providing an average discharge (8 years) of 817 cfs. Maximum estimated flow of 49,500 cfs occurred December 4, 1952, while the minimum discharge, zero flow, was observed many times during the summer of 1954.

In addition, the city of Little Rock diverts 32 cfs from Lake Winona on Alum Fork and, after use and waste treatment, this water is discharged to the Arkansas River.


Benton Dam Site
GARLAND
HOT SPRINGS
PULASKI
LITTLE ROCK
BENTON
SALINE
MALVERN
HOT SPRING
GRANT
SHERIDAN
JEFFERSON
CARTHAGE
PINE BLUFF
PRINCETON
DALLAS
RISON
CLEVELAND
FORDYCE
LINCOLN
CALHOUN
HAMPTON
WARREN
RYE
MONTICELLO
HERMITAGE
DREW
MOROBAY
BRADLEY
UNION
ASHLEY
Lake Winona
Middle Fork of the South Fork of the Saline
South Fork of the Saline
Saline River
Arkansas River
Ouachita River
Moro Creek
Bayou Creek
L'Aigle Creek
SCALE IN MILES
10 0 10 20
BENTON RESERVOIR
SALINE RIVER ARKANSAS
VICINITY MAP
U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII DALLAS, TEXAS
HJS

6-A FIGURE 1

Water Quality[4,5/]

Water quality data are available for the Rye and Benton gaging stations. In addition, samples for raw water quality determinations are collected routinely by the water works operating personnel at Benton and Bauxite, both of which use the Saline River as a source of water supply.

Water from the Saline River in its upper reaches is of very good quality, requiring a minimum of treatment for most municipal and industrial uses and changes only slightly in quality between Benton and Rye. Small amounts of color and hardness are added along its course. Typical results of chemical analysis are shown in Table 1.

Table 1[4/]

Average Water Quality - Saline River
Water Year 1955

	Benton Gaging Station	Rye Gaging Station
Ca - ppm	13	11
Mg - ppm	3.1	3.0
Na - ppm	2.4	8.9
HCO_3 - ppm	52	35
SO_4 - ppm	4.7	22
Cl - ppm	3.1	4.3
NO_3 - ppm	1.5	2.1
Dissolved Solids - ppm	68	76
Total Hardness - ppm	48	51
Carbonate - ppm	45	40
Noncarbonate - ppm	3	11
Specific Conductance	104 microhmos	129 microhmos
pH (mean)		7.0
Color - ppm	15	24
Mean Discharge (samples)	1,136 cfs	1,323 cfs

The quality indicated in Table 1 has remained essentially unchanged in the past few years.

Pertinent Data[2,6/]

The proposed multipurpose dam for the Benton Reservoir project will be of the earthfill type. Data covering its design features are shown in Table 2.

Table 2

Pertinent Data
Benton Reservoir, Arkansas

Drainage Area, square miles	563
Elevations:	
Minimum Pool, m.s.l.	300.0
Maximum Pool and/or Water Supply Pool, m.s.l.	351.0
Spillway Crest, m.s.l.	320.0
Surcharge Pool, m.s.l.	360.9
Top of Dam, m.s.l.	366.0
Volumes:	
Minimum Pool, ac.-ft.	21,300
Power and/or Water Supply Pool, ac.-ft.	340,400
Surcharge Pool, ac.-ft.	139,000
Firm Yield, mgd	300

IV. DESCRIPTION OF STUDY AREA

The Saline River Basin is roughly crescent shaped, approximately 130 miles long, and 20 to 30 miles wide, and includes an area of mountainous terrain at its headwaters, low hill country through the major central portion, and a small delta just before joining the Ouachita River about 12 miles north of the Louisiana state line[2/] See Figure 1. The study area includes the following counties which are in whole or part within the Saline River Basin: Saline, Hot Spring, Dallas, Grant, Cleveland, and Bradley. In addition, forest resources in Calhoun, Ashley, and Drew Counties were taken into account.

Small portions of the Saline River's watershed lie within Garland, Pulaski, Jefferson, Lincoln, Calhoun, Ashley, and Drew Counties. However, since the major portions of these counties are located on other watersheds, their significance to the study was not considered great enough to be included.

The Saline River Basin runs, in general, in a southerly direction and is bounded on the east by the Arkansas River Basin and on the west by the Ouachita River Basin.

Climate[2/]

The climate of the Saline River Basin is mild, having a mean annual temperature of 62°F. January is coldest with a mean temperature of 41°F, while July is warmest with 81°F mean. Recorded high and low are 115°F and -15°F, respectively. Average growing season is about 227 days.

This basin lies in a region of moderately heavy rainfall, averaging about 50 inches. The heaviest rainfall usually occurs during April and May, while the lightest happens during September and October.

Principal Communities and Industries

The major population centers within the study area are Benton, Bauxite, Warren, Fordyce, Malvern, and Sheridan. Of these, however, only Benton, Bauxite, Warren, and Sheridan are located on the Saline River watershed. Both Fordyce and Malvern are on the Ouachita watershed.

The upper portion of the Saline Basin contains the largest bauxite deposit in continental United States and the region's outstanding industry is alumina production from this mineral. (Alumina, Al_2O_3, ore which is electrolytically reduced to obtain aluminum.) Aside from the alumina industry there is no other large-scale industrial activity.

The remainder of the basin is agricultural with a growing forest products industry producing pulpwood and saw timber. This area is ringed by Arkansas' only pulp and paper mills, located at Pine Bluff (on the Arkansas River), Camden (on the Ouachita River) and Crossett (on Coffee Creek, a tributary to the Ouachita River).

V. ECONOMICS AND POPULATION

Municipal and industrial water demands will be centered at the principal cities in the area. Since industrial expansion, population growth, and an accompanying increase in water requirements depend to a great extent upon the presence of natural resources and their use, the study area's development can best be projected by examining the basin's economic environment, past and present.

Extractive Industries

Minerals 7/

Arkansas leads our nation in bauxite and barite production. Both operations are located within the study area for this project. Saline County's Benton-Bauxite area deposit is thought to be nearly inexhaustible at present production rates. Alcoa's Bauxite alumina plant has a capacity of 420,000 tons per year, while Reynolds Metal's Hurricane Creek plant in this area has a capacity for 730,000 tons per year Hot Spring County is outstanding in barite production. The remainder of the area offers little in mineral production other than sand and gravel.

In addition to bauxite, Saline County also produces clay, lime, talc, sand and gravel, and stone. Hot Spring County's barite production is augmented by clay, coal, sand and gravel, and gem stones. The value of minerals produced has gradually declined from $21,000,000 in 1954 to $14,000,000 in 1958. See Table 3.

Table 3 7/

Value of Mineral Production - 1953-1958
Saline, Hot Spring, and Bradley Counties, Arkansas
(Note: Other counties in study area have no significant production.)

Year	Saline	Hot Spring	Bradley	Total
1953	$12,158,253	$ 5,465,121	$----------	$17,623,374
1954	14,944,785	6,225,063	----------	21,169,848
1955	14,053,992	5,807,661	----------	19,861,653
1956	12,076,860	5,814,046	50,873	17,941,779
1957	10,870,548	5,440,595	6,128	16,407,271
1958	11,354,884	2,829,376	6,007	14,190,267

There presently is a limited amount of exploration for gas and oil in the southern portion of the Basin, since it lies relatively close to the rich El Dorado region. Some gas has been discovered.

Forest Resources[8]

The six-county study area has increased its commercial forest area from 1,996.3 million acres in 1934 to 2,117.9 million acres in 1959, which means that the portion covered by forest has increased from 79.3 to 84.9 per cent in 23 years. Additional planting of pine is being carried out in the area. It should be noted that the majority of this forest area is owned by large corporations. These organizations employ professional foresters who use modern forest management techniques to provide maximum yield per acre from this land.

For a number of years the hardwoods were being culled out in great quantities and replaced by pine planting. Growth rate dropped behind harvest. Recently this lagging trend has been reversed in most of this region.

Agriculture[9]

Agriculture's contribution to the economy of the study area has been in a decline in recent years. The number of farms has steadily decreased from 8,482 in 1945 to 6,783 in 1954. Coupled with this decline has been a significant reduction in the acres of cropland harvested from 164,448 acres in 1945 to 92,227 acres in 1954.

Although the value of crops sold advanced from 1945 to 1950, the decline from 1950 to 1954 carried below the 1945 level. However, the value of livestock and livestock products has experienced a steady gain in value, at least partially offsetting the loss of value of crops sold. Table 4 illustrates this situation.

Table 4[9]

Value of Crops and Livestock Sold
Saline, Grant, Hot Spring, Dallas, Cleveland, and Bradley Counties, Arkansas

Year	Value of Crops Sold	Value of Livestock Sold	Total
1945	$1,923,758	$2,112,452	$4,036,210
1950	3,433,400	3,266,395	6,699,795
	3,050,232*	2,353,764*	5,403,996*
1954	1,539,685	3,625,146	5,164,831
	1,266,083*	2,853,352*	4,119,435*

*Adjusted to 1945 value of the dollar

Manufacturing[10/]

The manufacturing base has grown dramatically in the period between 1947 and 1958. While the total number of employees has not increased to a very great extent, the area's output, measured as value added, has jumped from about $29,000,000 in 1947 to $73,000,000 in 1959 ($63,802,000 in 1947 dollars). This increase of roughly 150 per cent is centered in Saline and Hot Spring Counties and results from the growth of the alumina-aluminum industry. Saline County has two large alumina production plants in the Benton-Bauxite area. Hot Spring County has an alumina reduction (aluminum ingot producer) plant at Jones Mills, northwest of Malvern. (This aluminum plant is located on the upper Ouachita River watershed.)

The number of firms employing 20 or more has increased by only two from 1947 to 1954. However, the slack created by the shift away from lumber products, exclusive of furniture, has been taken up by primary metals (alumina, in this case) and chemicals and allied products. Details are shown in Table 5.

Table 5[10/]

Number of Firms by Size and Type of Manufacturing
Saline, Grant, Hot Spring, Dallas, Cleveland, and Bradley Counties, Arkansas - 1947 and 1954

Type of Manufacturing Firms	Number with 20 - 99 Employees		Number with 100 & over Employees		Total Number of Firms with over 20 Employees	
	1947	1954	1947	1954	1947	1954
Food and kindred products	-	1	-	-	-	1
Textile mills	-	-	1	1	1	1
Apparel and related products	-	1	-	-	-	1
Lumber and products, excl. furniture	23	20	9	8	32	28
Furniture and fixtures	-	-	2	3	2	3
Chemical and allied products	-	-	1	2	1	2
Stone, clay, and glass products	1	1	2	2	3	3
Primary metals	-	1	1	2	1	3
Misc. manufacture	2	2	-	-	2	2
	26	26	16	18	42	44

Retail Trade[26] and Service Establishments[11]

Commercial developments usually follow the growth patterns of a region's major industries. This area is a study in contrasts. There are three counties which have broken away from being almost wholely agricultural, while the others are almost completely dependent upon agriculture or farm-based industry.

The number of retail trade establishments decreased slightly from 1948 to 1956. At the same time, the number of employees increased slightly and sales volume rose by more than 50 per cent. The major gain in employment and sales volume occurred in Saline County. Some increase in employment and sales is evident in Hot Spring County. The overall changes can be observed in Table 6.

Table 6[26]

Retail Trade Developments
Saline, Grant, Hot Spring, Dallas, Cleveland, and Bradley Counties, Arkansas

	1948	1954	1958
Number of Establishments	1,027	894	896
Number of Employees	1,750	1,723	2,052
Sales Volume ($1,000's)	39,378	54,419	62,567

The data available for service establishments do not cover so great a period as the other information presented; however, it can be viewed as substantiating in part the previous findings. Between 1948 and 1954, the number of service establishments increased from 225 to 311 with major gains occurring in Saline, Hot Spring, and Bradley Counties. During the same period, the employment in these places of business expanded 32 per cent, while sales volume increased 1.3 times. Outstanding dollar volume gains were registered in Saline, Hot Spring, and Bradley Counties, which are developing industrial bases.

Population[12]

The population structure in the Saline River Basin has been undergoing considerable change during the last 50 years. In 1910, there was a total population of 81,724. Of this total, 68,780 were living on farms or outside of organized settlements and can be classed as rural. The remainder, 12,944, were residents of municipalities.

By 1940, the area's population had grown to 93,694 with a municipal population of 21,327. All of the towns had expanded somewhat without any one registering an outstanding gain. From 1940 to

the present, a definite trend has been established. The estimated municipal population has doubled to approximately 42,000 while the rural population has dwindled to about 48,000. This decrease in rural residents has more than offset the municipal growth and is reflected in an overall population decrease.

Likewise, between 1940 and the present, three areas have emerged as major population centers, having evolved to their existing position through industrial development. The Benton-Bauxite area has nearly quadrupled in the last 20 years, while Warren has more than doubled and Malvern has grown to nearly two times its size in 1940. The other municipalities have continued to expand also. Table 7 displays these trends.

Table 7[12/]

Rural and Municipal Populations and Major Municipalities Saline, Grant, Hot Spring, Dallas, Cleveland, and Bradley Counties, Arkansas

	1910	1920	1930	1940	1950	1960	
Study Area -							
Municipal	12,944	15,683	20,224	21,327	34,013	42,000	(est.)
Rural	68,780	67,450	68,284	72,367	58,367	47,849	(est.)
Total	81,724	83,133	88,508	93,694	92,380	89,849	(actual)
Benton	1,708	2,933	3,445	3,502	6,277	10,330	
Bauxite	---	---	---	---	2,459	2,000	(est.)
Malvern	2,778	3,864	5,115	5,290	8,072	9,518	
Warren	2,057	2,145	2,523	2,516	2,615	6,661	

Future Growth

From 1960 to 2010, our nation is expected to double in size. This growth will create a great increase in the need for goods and services. Although all parts of the nation will continue to contribute to the needs, the rate of increase in production will not be uniform in all areas. Regions and communities with factors which enhance their ability to produce and distribute goods will have better opportunities for growth.

An examination of the study area's ability to meet the increased demands will clarify the projections for the Benton-Bauxite and Warren areas. Both of the municipalities are located within the Saline River watershed, being adjacent to the stream, while Malvern is situated near the Ouachita River. Malvern will logically draw on the water resources of that basin and has been included in the study as the principal city in Hot Spring County, and also to indicate the presence of industrial growth in the general area. The

city of Fordyce is fourth largest in the study area but has not shown much growth potential to date. Like Malvern, it is situated within the Ouachita River watershed (on Moro Creek).

The Saline River Basin is rich in two natural resources - bauxite, for which expectations are that there will be a sustained demand for many years to come, and timber, for which an increase in demand is anticipated.

Bauxite-Alumina

The enormous deposit of bauxite near Benton in the upper basin will sustain present and anticipated alumina production levels well beyond the time set by this study. The demands for ore from this area fluctuate according to the overall aluminum market. This ore is not nearly so rich as that which can be imported. Also, transportation expense is a significant factor - most of the existing alumina reduction plants in this country are near low-cost sources of energy and water transportation. Since this area is competing with other areas which have inexpensive hydro-electric power (for alumina reduction) and low-cost transportation in and out of the bauxite refining area, it is not expected that more than moderate growth will take place. There are possibilities for industrial expansion in related chemical and primary metal fields in this area.

Pulp and Paper[8,13,14]

The southwest Arkansas forest area begins just south of Benton and extends south and west into Louisiana. Warren, Bradley County, is located in the most densely forested area of Arkansas. Furthermore, it lies just off the center of a triangle formed by the three pulp and paper producing cities in Arkansas - Pine Bluff, Camden, and Crossett.

Expectations are that by 2010 the growing demands of the United States for paper products will require approximately 96 million tons of wood pulp annually. This pulp and paper products output will use an estimated 132 million cords of pulpwood. In 1952, Arkansas produced about 2 per cent of the pulpwood in the country (although the state ranks eighth in total growing timber stock). By 1957, this had grown to approximately 3.5 per cent. Arkansas' total output of cordwood rose from 0.6 million cords in 1952 to 1.2 million cords in 1959. Increased production is expected to keep pace with demands. Assuming that 4 per cent of the pulpwood (pulp and paper) will be produced by Arkansas in 2010, the pulpwood output should be approximately 5.3 million cords.

Cognizance should be taken of the fact that pulpwood requirements and product output vary from process to process and even from mill to mill using the same basic process. Likewise the number of employees required per ton of output is highly variable. Therefore, average figures were derived from data on the existing paper and pulp industries in Arkansas[15]. Past and present production in Arkansas has been that associated with the Kraft process, so it is further assumed that this process and its refinement will continue in use. Based on an overall output of one ton of product requiring 1.75 cords of pulpwood, Arkansas will produce an estimated 3 million tons of product annually. (Note: This is greater than the 1.4 cords per ton that is indicated for the total U. S. output, since a pine pulpwood and Kraft process type of operation requires more wood per ton of output than most other processes.)

The present manufacturing employment in Arkansas is estimated at 85,000[16]. Of this, approximately 6 per cent or about 5,000 are employed in pulp and paper making. This includes converters (i.e., paper and paper products makers), since all of the mills in Arkansas, and nearly all those in the south, are integrated mills...continuous cordwood to woodpulp to paper operations. If employment grows directly in proportion to paper production, the forecast 2010 employment in this segment of Arkansas' industry should be 5.3/1.2 X 5000 = 22,000. This would be roughly 10 per cent of the extrapolated manufacturing employment in Arkansas in 2010[17].

The geographic distribution of Arkansas' pulp and paper production will be governed by two factors: location and availability of pulpwood and the availability of process water together with an adequate means of waste disposal after treatment.

The most productive of Arkansas' 19 million acres of forest are located in the southwest forest region. The majority of the wooded area in and adjoining the Saline Basin is owned by forest products companies. The forest management practiced on these organizations' holdings is responsible for the better harvests achieved in this region.

Approximately 50 mgd of the 66 mgd used for pulp and paper production in 1957 was ground water. Only the Camden area operation utilizes a surface source of supply, the Ouachita River. Expansion in the ground water using areas is extremely limited due to lack of adequate quantities of water. Pine Bluff area wastes are released to the nearby Arkansas River, which is not of suitable quality for municipal or industrial use, being highly mineralized; Crossett area wastes are discharged to the Ouachita River downstream from Camden.

Both the Saline and Ouachita River Basins can support a considerable pulp and paper industry if sufficient water of suitable quality is provided. Employment in this industry in the Warren area

could grow to 8,000 - 9,500 when fully developed. This area would produce an estimated 1.3 million tons of paper annually (3,500 tons daily). Based on 1.75 cords of pulpwood per ton of output, approximately 2.2 million cords will be needed for this production level.

A very well managed acre can produce about one cord of pulpwood annually. Average well managed acreage may produce 2/3's of this. Thus, the total 5.3 million cord harvest for 2010 in Arkansas will need roughly 8 million acres of well managed growing space (42 per cent of the existing 19 million acres). In 1959, roughly 50 per cent of the state's timber production went into pulpwood[18].

Since the forest area in the southwest region has been increasing gradually and growth is exceeding harvest, it would seem that there will be available enough pulpwood stock to support the Saline Basin's forecast paper industry in 2010.

Manufacturing (Other than Pulp and Paper)

While there has been a considerable amount of industrial expansion in the study area, there has not been a firm trend set outside of the bauxite-alumina and wood products industries. Future growth in the Saline River Basin can be expected. However, the industries will probably be somewhat diversified. Nearby Little Rock provides a good market for the output from some small to moderate-sized light industries. The ingot aluminum available from the Jones Mills alumina reduction plant (near Malvern) offers opportunities for some extrusion and fabrication expansion.

Good transport, highway and rail, is available at both Benton and Warren to move the output from these areas to regional, national and international markets.

Benton

The situation in and around Benton is very favorable for continued growth. There are indications that this area is becoming a "commuter" community for nearby Little Rock.

The population decrease in the community of Bauxite is a positive factor for Benton's growth. This small community is a "company town," owned and operated by ALCOA. The strip mining operations are rapidly entering the municipal area, since the town is located on the bauxite ore deposit. Portions of the town have already gone out of existence and expectations are that the rest of the town will follow in the foreseeable future. The population from this town will be absorbed in and around the Benton municipal area.

Benton State Hospital

Just outside of Benton, the State of Arkansas maintains a hospital for the treatment of the mentally ill. This institution has a presently estimated population of 3,000 to 3,500. Ample area is provided on the existing grounds for doubling or even tripling its capacity. By 2010, the population of these facilities can be expected to expand to roughly twice that now or 6,000 to 7,000.

Other Growth Factors

It is expected that retail and service establishments will expand in number and employment to keep pace with the increased population in the communities.

A large industrial site has been set aside by the Benton Industrial Development Commission and successful efforts are being made to create a favorable atmosphere for operations. Three small companies, employing 160, have settled in Benton since August, 1958. Similar circumstances exist in Warren, where a plant employing 250 recently started production.

Population Projections

The population of the study area will probably grow 75 per cent to 157,000, based upon the industrial expansion forecast. See Figure 2. The rural population, however, will continue to shrink, ultimately leveling off at 40,000 more or less. At the same time, the municipal population will nearly triple, reaching approximately 117,000. Figure 2 illustrates the anticipated population of the major employment areas as well as past growth trends.

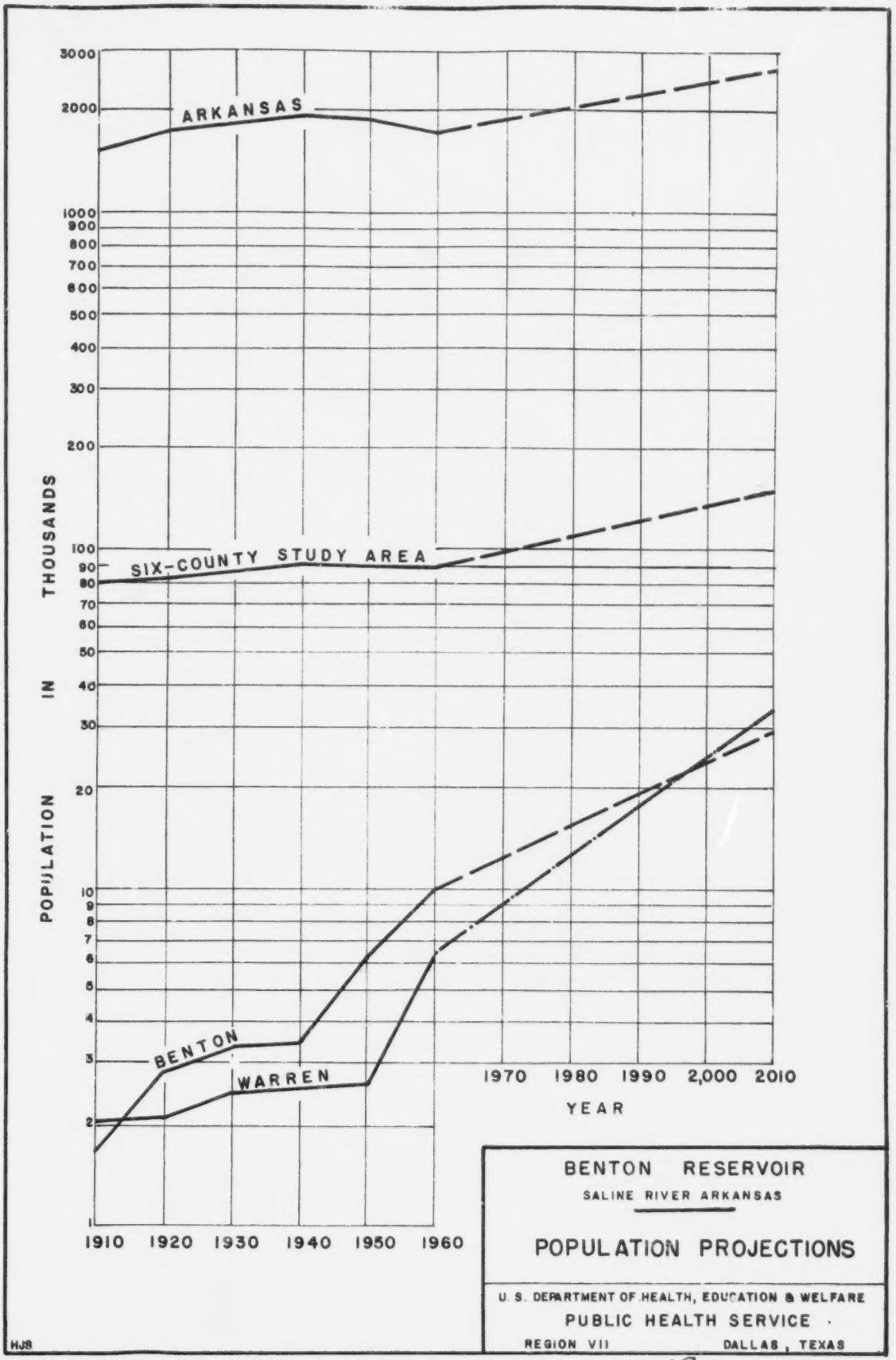

3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
POPULATION IN THOUSANDS
ARKANSAS
SIX-COUNTY STUDY AREA
BENTON
WARREN
1910
1920
1930
1940
1950
1960
1970
1980
1990
2,000
2010
YEAR
BENTON RESERVOIR
SALINE RIVER ARKANSAS
POPULATION PROJECTIONS
U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VII
DALLAS, TEXAS
HJS

FIGURE 2

VI. WATER REQUIREMENTS

Present Water Use

The existing municipal and industrial water use is shown in Table 8 along with source of supply and estimated dependable yield data.

Table 8

Present Municipal and Industrial Water Use
Saline River Basin, Arkansas

Water System	1960 Pop.	Est. Avg. 1960 Use	Source of Supply	Est. Yield
Benton	10,330	0.92 mgd	Saline River (	
Benton State Hosp.	3,500	0.45 mgd est	Saline River (	6 mgd
ALCOA - Bauxite	2,000 est	2.6 mgd est	Saline River (	(10 cfs)
(Note: 0.34 mgd - treated to serve mill and town - 1959 avg.)				
Reynolds Metals	900 emp	3.5 mgd	Hurricane Creek Reservoir	5 mgd
(Note: Treated 0.95 mgd - 1959 avg.)				
Warren	6,661	0.75 mgd	3 Wells	2 mgd
(Service to 8,000±)				
Sheridan	1,960	0.19 mgd	2 Wells	1 mgd

Municipal water requirements have increased in step with population growth, while the industrial use has remained more or less constant over the last five years.

Existing Sources

As shown in Table 8, the northern portion of the Saline River Basin uses surface water exclusively to meet the municipal and industrial needs. There is very little ground water available in this area.

Enough ground water is available in the southern portion of the basin to serve its requirements, provided that there is not an appreciable increase in municipal consumption. There is no evidence of ground water available for development to serve a water using industry. Wells drilled in the northern part of the Saline River Basin are not dependable for yields in excess of 50 gpm.

There are two water supply reservoirs on the Saline River headwaters: Lake Winona on Alum Fork, which provides an average of 32 cfs (21 mgd) for the Little Rock Water Works system and Brushy Creek Reservoir (Lake Norrell), on a tributary to the North Fork.

Brushy Creek Reservoir was constructed as the result of findings made by the Corps of Engineers, Vicksburg District, reported in 1951. It provides a safe yield of 10 cfs (6 mgd) for water supply at Benton. During periods of extreme drought, this would be the entire flow in the Saline River at this point, since the discharge can drop to zero flow as in 1954.

Reynolds Metals Company constructed a dam on Hurricane Creek to provide water for its Hurricane Creek plant operations.

The quality of the surface waters in this region is very good as indicated by the results of chemical analysis given previously for the Saline River at Benton. Hurricane Creek provides an equally good quality water supply.

The ground water is of variable quality obtained from relatively deep wells. Sheridan's water is obtained from the Tertiary Sands (539' deep).[15] Sheridan provides iron removal, aeration, filtration, poly-phosphate treatment, and hypochlite disinfection; while Warren, utilizing the Sparta Sand aquifer (1,050' deep) simply chlorinates. Table 9 reveals the contrast between these two ground waters.

Table 9[5]

Ground Water Quality - Saline River Basin

	Warren	Sheridan
Date	May, 1957	November, 1957
Source	Well #1	Well #1
pH	8.0	6.1
Alkalinity - ppm		
P	0	0
Total	162.0	22.0
Total Solids	240.0	66.0
Hardness - ppm		
Total	13.0	21.0
Carb.	13.0	0
Noncarb.	0	21.0
Cl - ppm	13.0	5.0
SO_4 - ppm	1.5	2.5
Ca - ppm	3.8	5.7
Mg - ppm	0.89	1.65
Fe - ppm	0.07	3.20
Mn - ppm	0	Tr.
F - ppm	0.30	0.05
Al - ppm	----	0

Additional Water Needs

Future municipal requirements are contingent upon industrial growth, inasmuch as most of the population will obtain its livelihood either from the manufacturers or employees. Therefore, it is assumed that industrial water will be provided to support the industrial expansion possible in the Saline River Basin.

Benton Area

Approximately 5.75 mgd (avg.) will be required in the upper Saline River Basin in the year 2010 to serve the forecast population of 30,000 on the Benton municipal system and 7,000 persons at the Benton State Hospital. The total industrial demand in this area can be expected to reach approximately 16.0 mgd (avg.) at that time, making a total average municipal and industrial water requirement in the Benton area of 21.75 mgd.

Brushy Creek Reservoir would be capable of providing 13 mgd if the water were piped directly to the Benton area water intakes to avoid the losses in transit. This coupled with the estimated 5 mgd available in Hurricane Lake would still fall short on the forecast requirements by 3.75 mgd. However, these water demands are dwarfed by those of the Warren area ... lower Saline River Basin.

Warren Area

The Warren area of the lower Saline River Basin could experience considerable growth, specifically connected with the pulp and paper industry, including some conversion, provided adequate water supply is furnished. Approximately 5.25 mgd (avg.) municipal water will be needed by the forecast population of 35,000 in this area.

South central Arkansas holds the promise of a large pulp and paper products industry. Based on water use in current operations, approximately 125 mgd will be required to meet the 2010 forecast output in this area. Although this is a sizable percentage of the 290 mgd state-wide water needs for pulp and paper production, the expected timber resource development will be able to provide raw materials for industrial development to this extent.

Existing processes require from as little as 18,000 gallons up to more than 100,000 gallons per ton of production. Arkansas' paper industry, in 1957, required about 35,000 gallons per ton (or 13,500 gpd per employee; 20,000 gallons per cord using 1.75 cords per ton). This compares well with Louisiana's operations for 1955 when 122 mgd was required to produce 1.6 million tons or 28,000 gallons per ton. (Louisiana's forests border Arkansas' and are similar.)[19,20]

The expected industrial water needs for this area assume limited production expansion in one of the two paper mill areas now using ground water in their processes. It is quite possible for the Crossett area to expand by taking water from either the Saline or Ouachita Rivers as the pumping distance from either is eight or nine miles. However, large growth of this industry at Pine Bluff depends upon the quality of the Arkansas River improving a considerable degree. The Arkansas River presently affords a good waste disposal media, but its quality precludes many other uses.

Production in the Camden area likewise is limited by the availability of a sufficient quantity of water. Further development of the Ouachita River could remedy this problem and the probability of this occurring is quite good. The DeGray Project, on the Caddo River, a tributary to the Ouachita River, upstream from Camden, is being studied. It is designed to provide storage for a safe yield of 250 mgd for municipal and industrial water supply purposes.

Stream Quality Maintenance

Protection of the quality of Arkansas' waters is primarily the responsibility of the Arkansas Water Pollution Control Commission. Stream quality criteria and subsequent regulations governing waste discharges, and other pronouncements on the maintenance of water quality within Arkansas' boundaries, come from this agency. The use of water will almost inevitably result in the production of some liquid wastes which, even after a high degree of treatment, will degrade the quality of the receiving stream. It is essential that recognition be given to the need for flows which must be maintained in the receiving stream if the quality of its waters is to be kept at reasonable levels. Therefore, estimates of these stream flow needs have been made, since they are an inseparable part of the water demand from a reservoir if unimpounded flows in the stream have an insufficient assimilative capacity. Although the final determination and acceptance of stream quality must come from the Arkansas Water Pollution Control Commission, it is believed that the maintenance of stream flows at levels indicated will result in quality conditions reasonably acceptable to them.

All municipal wastes receive at least primary treatment prior to release to the Saline River watershed. Both Benton and Bauxite provide secondary treatment for their wastes. A high degree of treatment is given the waste produced by the small town of Rison (est. 1960 population - 1,000) before discharge to a small tributary to the Saline River. Warren currently operates two primary type treatment plants.21/ These will be abandoned when the city's proposed new secondary treatment plant is completed.

The relatively small quantity of industrial wastes produced in the basin also receives treatment before being sent to the Saline River. Both alumina producers in the Benton area lagoon their wastes.

The expected waste loading in the upper reaches of the Saline River should be easily assimilated and will probably be completely stabilized before reaching the Warren area, some 130 to 140 miles downstream from Benton. This is predicated upon the flow requirements for the Warren area being provided and a minimum of secondary treatment being given all wastes.

Maintenance of a stream flow of sufficient volume to assimilate treated wastes without impairment of water quality is essential for optimum use of water resources of an area. It may be necessary to supplement stream flows below the reservoir by releases from it to be assured that stream quality is kept at a level that will place no restrictions on water use and to maintain an acceptable environment for aquatic life.

A great deal of consideration must be given to the assimilation of the wastes which would be produced by the projected pulp and paper industry in the lower stretch of the stream. This waste load could have an effect not only on the Saline River but also the Ouachita River, a much larger stream which is joined 60 miles downstream.

The average biochemical oxygen demand (BOD) loading per ton of Kraft paper is 50 pounds (5-day).22/ Thus, for the forecast output of 3,500 tons/day, the total assumed waste load would be 178,500 pounds BOD/day (or a population equivalent of 1,071,000). With 90 per cent BOD removal for paper mill wastes and municipal wastes a reality, the total discharged waste load would contain about 18,500 pounds 5-day BOD/day (PE = 107,100).

The flow characteristics of the stream . . . whether it runs deep or shallow, fast or slow, smooth or broken . . . coupled with its temperature determine, for the most part, its organic waste assimilating capacity (BOD). Stream temperatures are available for the Ouachita River in this region.15/ These were assumed for the Saline River in the Warren area. The self-purification capacity of a watercourse can be determined only through detailed sampling and analysis. Since these data are not available, assumptions were made, based on experience on streams of similar character.

Minimum flows at Warren to maintain 4.0 ppm dissolved oxygen below that point will range from 5 mgd during the cooler part of the year up to 475 cfs during June, July, and August, the hot months. Water temperatures vary from a low of 49°F up to a high of 87° . . . average 68°F. The resulting annual average flow required would be 202 cfs (132 mgd).

The color of paper mill waste which would be carried into the stream is of equal or perhaps greater importance than the organic waste loading. While color in water has little sanitary significance, it is undesirable, aesthetically, and may stain materials or adversely affect some industrial processes. Pulp and paper production requires water which contains no more than 25 ppm of color (Kraft paper, bleached).[23] And, today's public demands a sparkling, clear water. Modern water treatment processes can reduce color from up to 150 ppm to the U. S. Public Health Service acceptable standard of not more than 20 ppm.[23,24] However, the cost of color removal at the upper limit is considerable.

The Saline River now has a natural color, caused by runoff from forest litter, etc., of about 25 ppm in the Warren area. Paper mill wastes have a color of approximately 250 ppm. While considerable time and effort have been spent in developing treatment for pulp and paper wastes, existing systems are incapable of reducing the color at a reasonable cost. Nevertheless, this pollutant must be removed before the water can be used; therefore, a reasonable level of color must be maintained in the stream if the stream's usefulness is not to be unduly diminished. A maximum color of 75 ppm in the stream in this area has been assumed as the criterion as the result of several conferences with officials of Arkansas' water pollution control agency.

Appearances are that there is some reduction (perhaps by adsorption) in color when a quantity of paper mill wastes is mixed with the waters of a stream containing a similar type of color, such as that produced by forest litter, in a lesser quantity. However, there does not seem to be, at the moment, any method available for predicting this reduction. Assuming a color of 250 ppm in the waste, 25 ppm in the Saline River and the 75 ppm criterion for the mixture, it will require something less than 648 cfs (435 mgd) to assimilate the color in this waste to an acceptable level.

It is probable that the color of the Saline River at Warren will be somewhat less than 25 ppm when the flow is augmented. Therefore, a flow of 260 cfs (170 mgd) would probably be adequate in meeting this problem. Additional study, as the industry develops, would be required to bear this out. Conditions could develop which would seriously curtail growth of the pulp and paper industry in this area due to the inability of the Saline River to assimilate the waste loading (color or organic). However, the provision for 260 cfs (170 mgd) waste assimilation flow should forestall this eventuality.

Plan for Supplying Future Requirements

The existing sources of supply will serve the municipal and limited industrial water requirements for some time. However, these sources do not provide for the needs of heavy water-using industry,

such as paper making. A reservoir at the site of the proposed project could be constructed to furnish the water requirements forecast. A release of 300 mgd (avg.) from this project would serve the forecast municipal and industrial needs of the lower Saline River Basin in the year 2010. This release would likewise provide for the future municipal and industrial water demand of the upper Saline River Basin (Benton area), as the water can be withdrawn, treated, used, the waste created treated and then returned to the stream for downstream use. It is expected that the runoff contributed by tributary streams between Benton and Warren will more than offset losses due to evaporation and percolation in the stream bed.

The quality of water to be obtained from the Saline River all along its course should be of good quality. Furthermore, the controlled flow conditions resulting from reservoir operations should reduce the color at Warren below the existing level (average 25 ppm).

There does not appear to be an alternative to this plan which even approaches feasibility. The Arkansas River could provide water in sufficient quantity, but is of poor quality. Transmission cost would be a negative factor. The Ouachita River to the west could also supply water in the quantity and of the quality required. Impounding plus transmission costs likewise would render this source considerably more costly than the proposed plan.

VII. BENEFITS OF STORAGE

The alternative cost method employed in determining the benefits from this project is essentially based on the question, "What will be provided to meet the water requirements of the area in the absence of the project under consideration, and . . . how would the cost of obtaining water from this source compare with that for securing water from the project?" Since there is no other source available which would not incur considerable transmission costs, the most feasible alternative to the proposed project would be a single purpose project at the Benton site.

It seems certain that the expanded need and use of water for municipal and industrial purposes forecast in the preceding portions of this report will not materialize in the absence of suitable water supply, such as the proposed project. The area population growth, likewise, will probably be quite a bit less than expectations.

Furthermore, the full industrial expansion forecast cannot be achieved without the waste assimilation water being provided to maintain stream quality as required by Arkansas' pollution control agency. Evaluation of benefits of storage must be tempered in the light of these considerations.

Alternative Plan

The most feasible alternative to the proposed project is a single-purpose reservoir at the same site. Other sites are available, but would not yield the quantity of water required. All are on tributaries to the Saline River, upstream from the proposed site. Since the project and its alternative are at the same site, there will be no difference in treatment or transmission cost to be considered.

Water Supply Benefits[6/]

The net investment in the alternative reservoir would be $25,078,000, including interest during construction. Estimated annual operation and maintenance charges will amount to $130,000. Based on 4 per cent interest for 50 years, the annual charge for principal and interest would be $1,167,380, making the total annual cost of the use of this storage for a yield of 300 mgd, $1,297,380 (including maintenance and operation).

By way of explanation, this interest rate is chosen as being at or near that which prevails for financing over the 50-year period assumed as the economic life of the project by the Corps of Engineers. Although this period or interest rate is not now available to municipalities or industries, these conditions were assumed to meet the needs of this analysis.

Although the total storage requirement will provide yield of 300 mgd, the projected demand for municipal and industrial purposes will be only 130 mgd. The remainder is for water quality maintenance, which is of equal importance. An annual benefit of $562,000 can be attributed to the storage provided for a firm yield of 130 mgd municipal and industrial water.

Water Quality Maintenance Benefits[25/]

Various plans for water quality maintenance were considered, such as treatment and storage with controlled release. However, the dominating pollutant . . . the most troublesome constituent . . . is not BOD, solids, or sulfates, but color concentration. This characteristic of paper mill waste is extremely difficult to control and costly to remove by treatment. However, recently advances have been made in color removal from certain classes of paper mill wastes.

As previously pointed out, the Saline River's color assimilated capacity could limit the basin's development. The water required for waste (color) assimilation is therefore an operating need equal to the water for municipal and industrial purposes. Water for waste assimilation could be provided from storage in the proposed project or its alternative.

Based upon the cost of the most reasonable alternative, the storage provided for a firm yield of 170 mgd of water for stream quality maintenance would have an annual benefit of $735,180.

VIII. BIBLIOGRAPHY

1. Corps of Engineers, Drainage Area Data, Arkansas, White and Red River Basins, Tulsa, November, 1954, Sheets 168, 169.

2. Corps of Engineers, U. S. Army, Vicksburg District, Interim Review Report Ouachita River and Tributaries, Arkansas and Louisiana with Respect to Saline River Basin, Arkansas, Vicksburg, 24 September 1951.

3. Geological Survey Water Supply Paper 1561, Surface Water Supply of the United States, 1958, Part No. 7, Lower Mississippi River Basin, U. S. Government Printing Office, Washington: 1960.

4. Geological Survey Water Supply Papers 1292, 1402, Quality of Surface Waters of the United States, 1953, 1955, Parts 7 and 8, Lower Mississippi Basin and Western Gulf of Mexico Basins, U. S. Government Printing Office, Washington: 1959.

5. Arkansas State Board of Health, Bureaus of Sanitary Engineering, Chemical Data on Arkansas Public Water Supplies, 1958.

6. U. S. Army Engineer District, Vicksburg, Enclosure with a letter dated 27 July 1960, transmitting various data to Water Resources Section, U. S. Public Health Service, Region VII, Dallas, Texas.

7. U. S. Bureau of Mines, Minerals Yearbook (s), 1955 through 1958.

8. Southern Forest Survey Progress Reports, Preliminary Forest Statistics for Southwest Arkansas Counties, Forest Service, U. S. Department of Agriculture, New Orleans, Louisiana, 1959.

9. U. S. Bureau of Census, Census of Agriculture: Arkansas, 1950, 1954.

10. U. S. Bureau of Census, Census of Manufactures, 1947, 1954, 1958.

11. U. S. Bureau of Census, Census of Business, Selected Services, 1948, 1954.

12. U. S. Bureau of Census, Population Census, 1930-1960.

13. Forest Service, Timber Resources for America's Future, Forest Resource Report No. 14, U. S. Department of Agriculture, Washington 25, D. C., January, 1958.

14. Southern Forest Experiment Station Forest Service, Timber Supplies for Industry in Arkansas, Forest Resource Report No. 11, U. S. Department of Agriculture, Washington, D. C., 1956.

15. Noel H. Wood, Arkansas Water Resources, University of Arkansas, College of Business Administration, Industrial Research and Extension Center, June, 1959.

16. University of Arkansas, Industrial Research Center, 1957 Directory of Arkansas Industries, Arkansas Industrial Development Commission, Little Rock, Arkansas (Revised to April, 1960).

17. Conference with Ralph Gray, Regional Economist, Industrial Research and Extension Center, College of Business Administration, University of Arkansas, Little Rock, July 13, 1960.

18. Fred H. Lang, Arkansas State Forester, Letter dated August 18, 1960, stating 1959 timber harvest, addressed to U. S. Public Health Service, Dallas, Texas.

19. Louisiana Department of Public Works, Water, A Special Report to the Louisiana Legislature, Baton Rouge, 1956.

20. Bureau of the Census, Statistical Abstract of the United States, 1958.

21. U. S. Public Health Service, 1957 Inventory Municipal and Industrial Waste Facilities, Washington, D. C.

22. Willem Rudolphs, Industrial Wastes - Their Disposal and Treatment, ACS Monograph No. 118, Reinhold Publishing Corp., New York, 1953.

23. Babbitt and Dolan, Water Supply Engineering, McGray-Hill Book Company, Inc., New York, 1955.

24. U. S. Public Health Service, Drinking Water Standards, Washington, D. C., 1946.

25. Albert J. Herbert and Herbert F. Berger, A Kraft Waste Color Reduction Process Integrated with the Recovery System, National Council for Stream Improvement, Unpublished, (presented at 1960 Purdue Industrial Waste Conference).

26. U. S. Bureau of Census, Census of Business, Retail, 1948, 1954, 1958.